

# **Impact of barrier layer thickness on SST in the central tropical North Atlantic**

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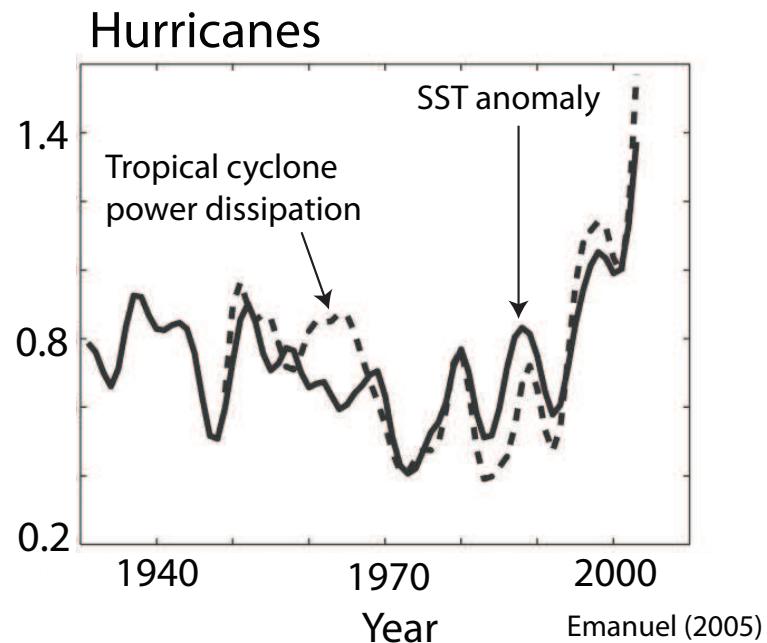
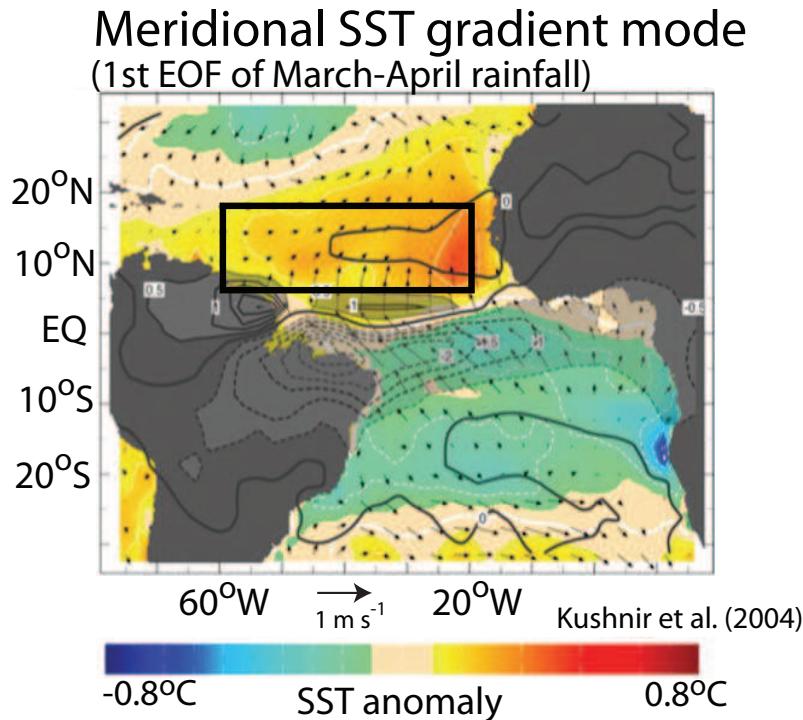
*NOAA/Pacific Marine Environmental Laboratory, Seattle, WA USA*

**Tropical Atlantic meeting, Toulouse, 3–6 February 2009**

- *Purpose of this study:* Investigate the impact of barrier layer thickness on the seasonal cycle of SST in the central tropical North Atlantic.
- *Approach:* Conduct a mixed layer heat budget analysis at three PIRATA mooring locations. Estimate the impact of barrier layer thickness on SST using a simple mixed layer model.

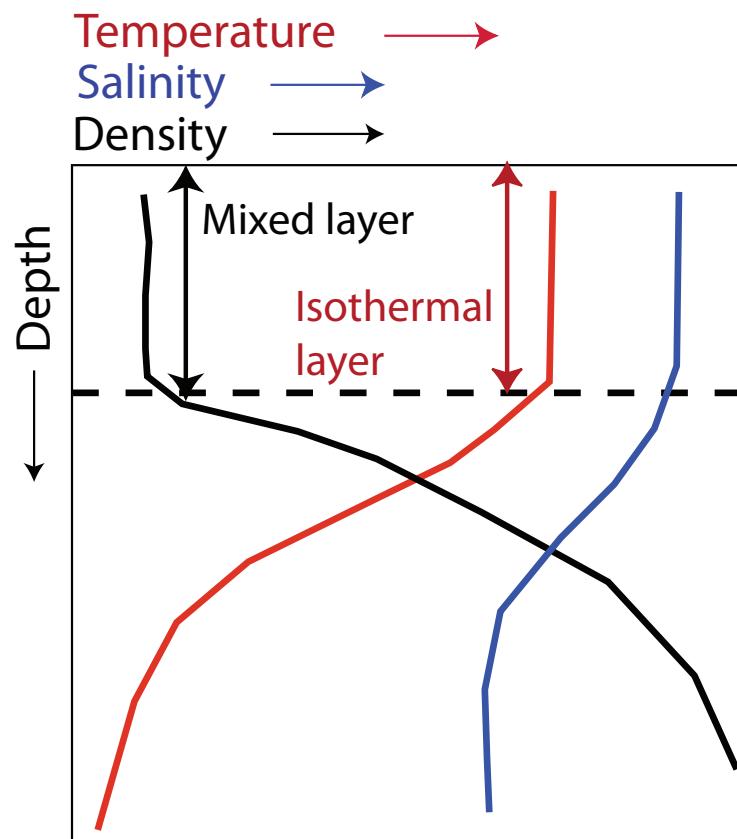
Foltz, G. R., and M. J. McPhaden, 2009: Impact of barrier layer thickness on SST in the central tropical North Atlantic, *J. Climate*, **22**, 285–299.

# Importance of tropical North Atlantic SST

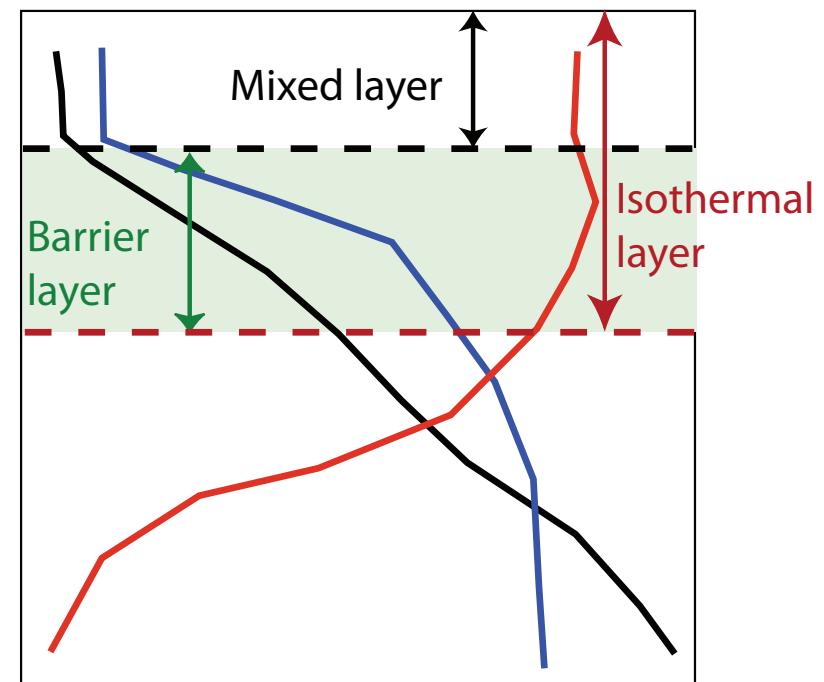


- SST gradient mode affects rainfall in Northeast Brazil and the Sahel
- Atlantic hurricane activity is strongly correlated with SST on interannual to decadal time scales

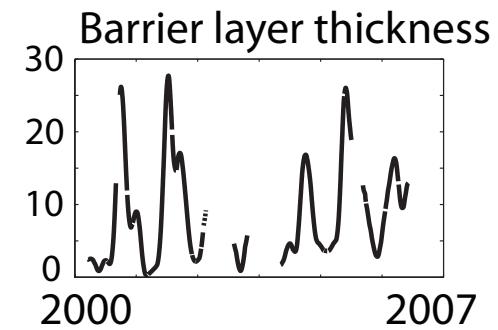
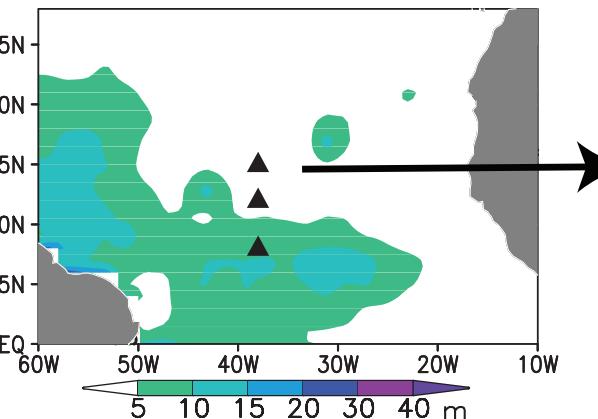
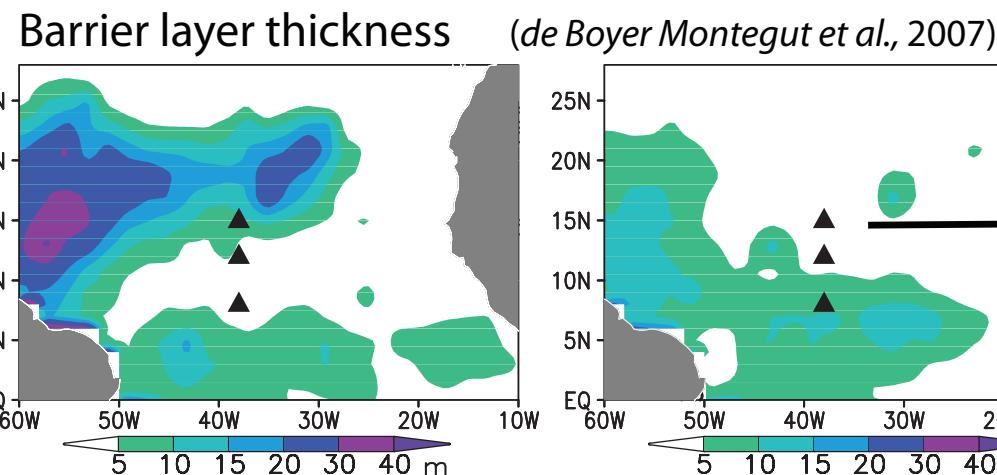
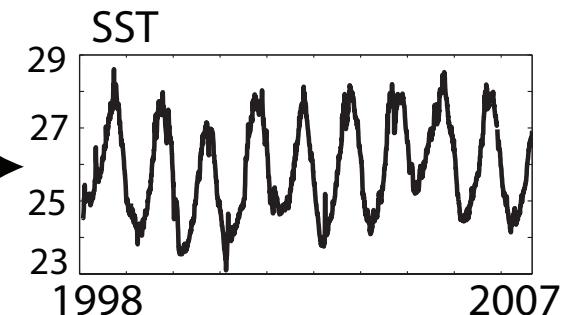
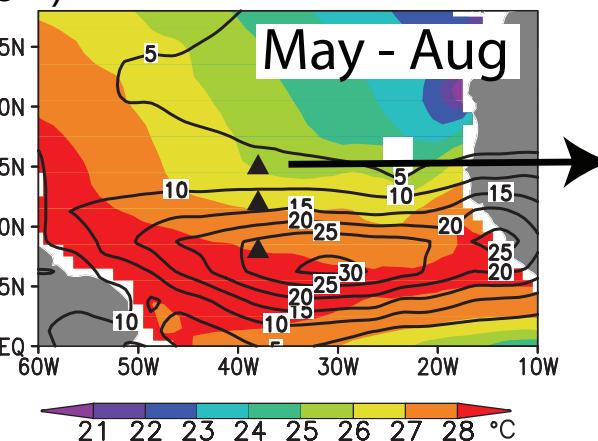
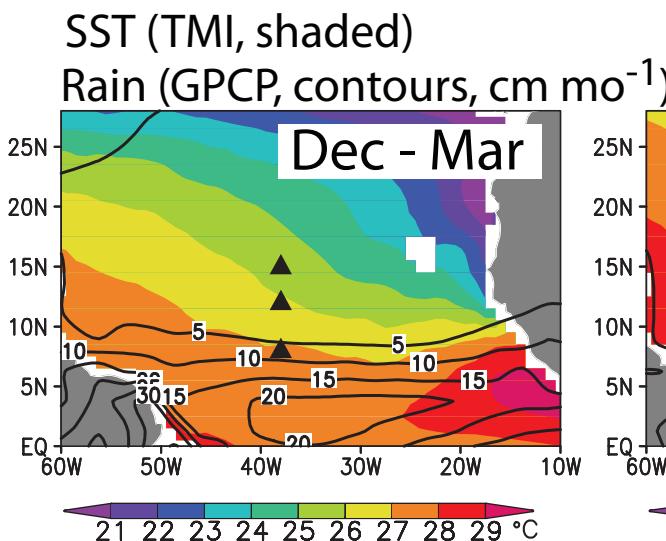
# Importance of barrier layers



- Barrier layers affect the rate of turbulent heat transfer across the base of the mixed layer  
(Vialard and Delecluse 1998;  
Maes et al. 2002; Masson et al. 2005)



# Seasonal cycle



# Data

- PIRATA moorings: Subsurface temp. (20-m vertical spacing), salin. (1 m, 20 m, 40 m, 120 m); sfc. shortwave, air temp., rel. humid., and wind speed. Daily averages, Jan 2000 – Aug 2007 (~6 years at 15°N, ~3 years at 12°N and 8°N).
- TMI SST gradients (daily, Jan 2000 - Aug 2007).
- Monthly climatological near-surface currents (Grodsy and Carton 2001).

# Mixed layer heat equation

$$\rho c_p h \frac{\partial T}{\partial t} = q_0 - \rho c_p h \mathbf{v} \cdot \nabla T + q_{-h}$$

**Mixed layer heat storage rate** →  $\rho c_p h \frac{\partial T}{\partial t}$

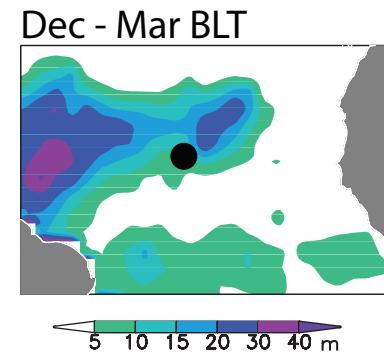
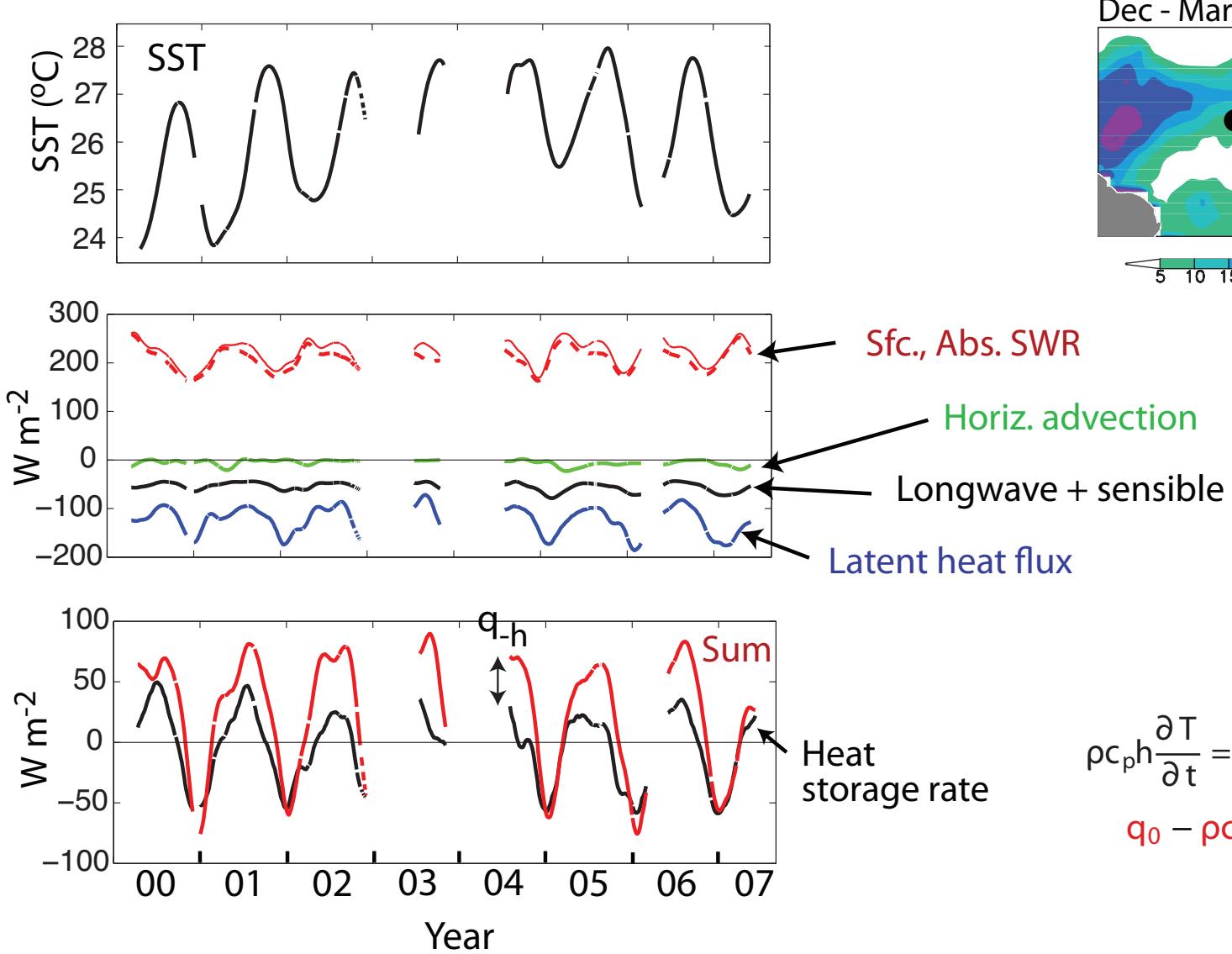
**Sfc. heat flux (LHF + Abs. SWR + LWR + SHF)** →  $q_0$

**Horiz. advection** →  $-\rho c_p h \mathbf{v} \cdot \nabla T$

**Vert. turb. mixing** →  $+ q_{-h}$

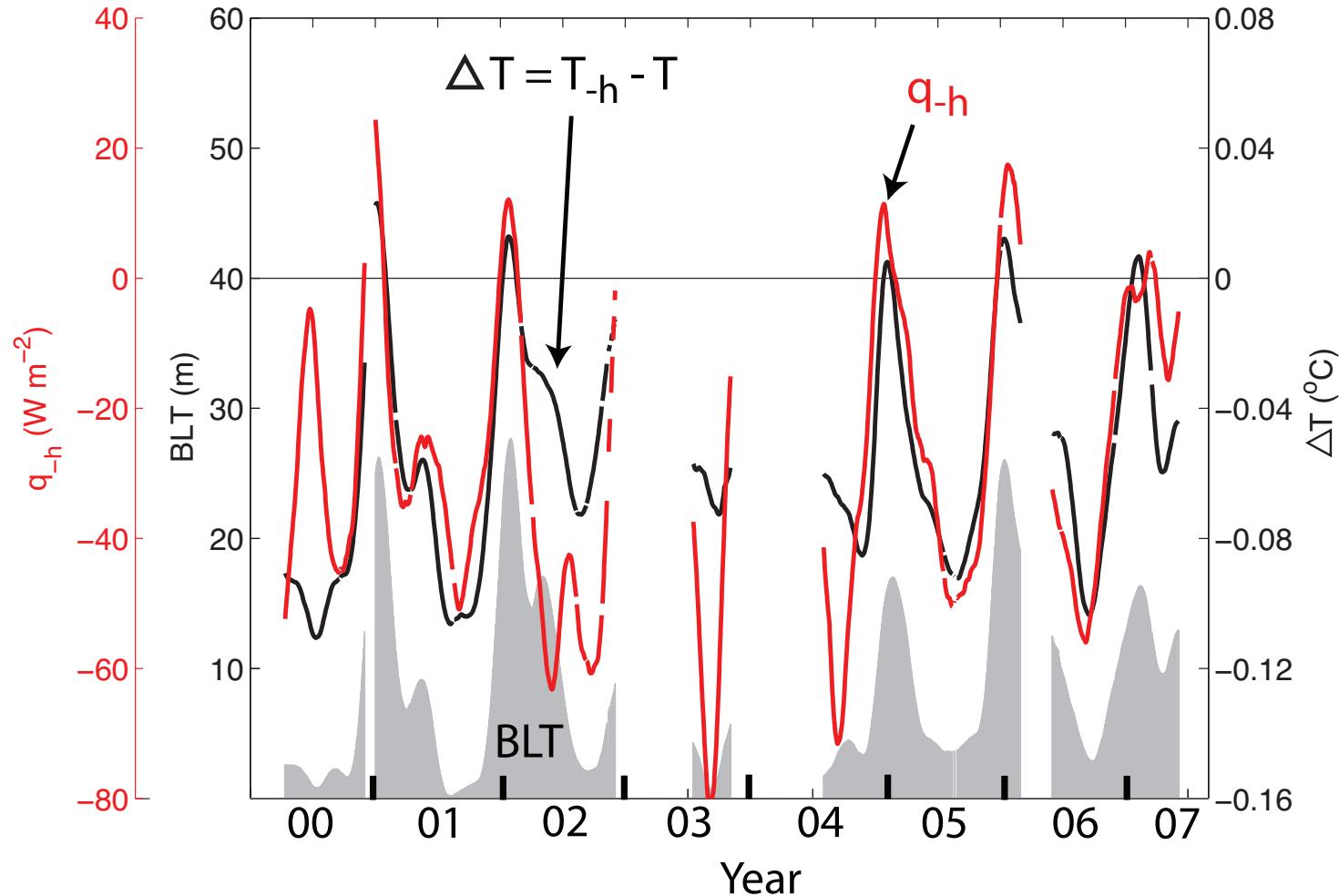
- $h$ : 0.03 kg m<sup>-3</sup> increase from 10 m
- $\mathbf{v}$ : monthly climatology
- $\nabla T$ : monthly TMI SST
- $q_{-h}$ : residual

# Mixed layer heat balance at 15°N, 38°W



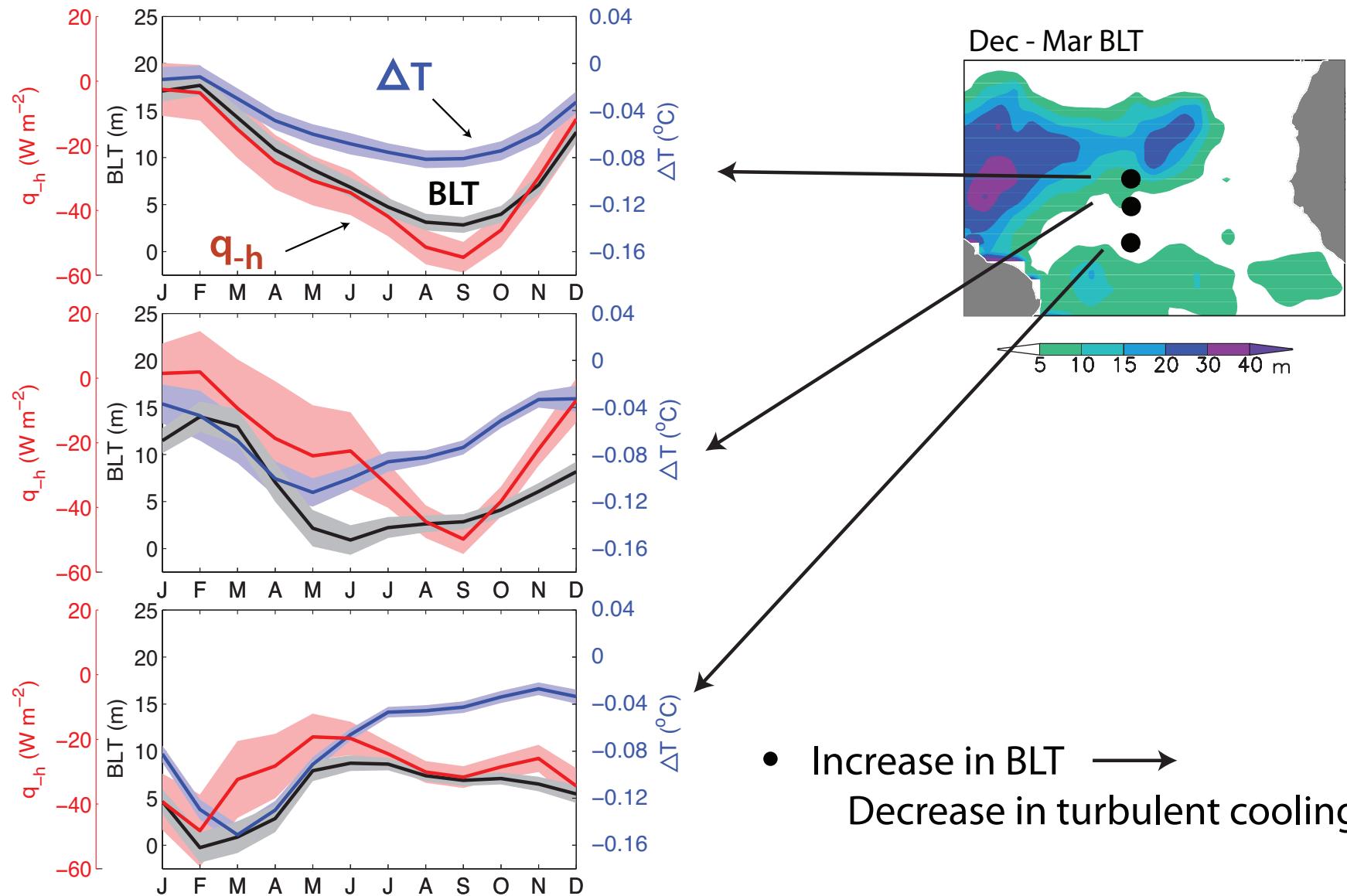
$$\rho c_p h \frac{\partial T}{\partial t} = q_0 - \rho c_p h \mathbf{v} \cdot \nabla T + q_h$$

# Barrier layer thickness and $q_h$ at 15°N, 38°W

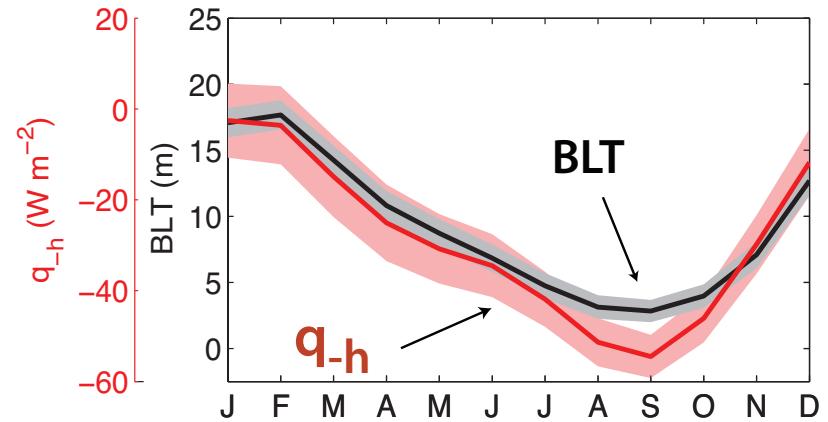
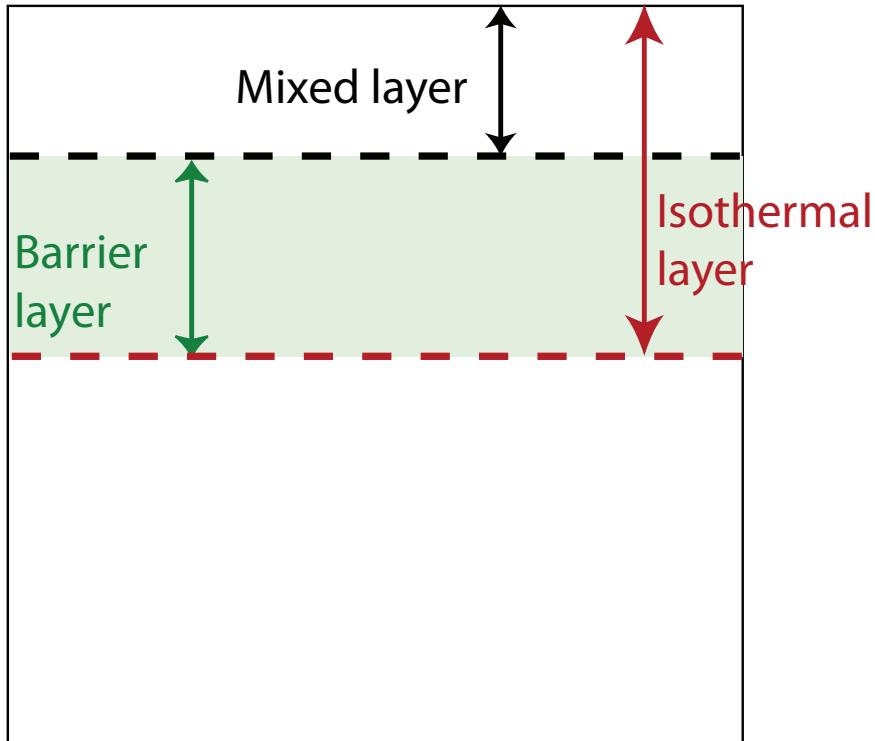


- Thick barrier layer  $\rightarrow$  small  $\Delta T$   $\rightarrow$  weak  $q_h$

# Seasonal cycles at the mooring locations



# Impact of barrier layer thickness on SST



- Thicker barrier layer results in thinner mixed layer and smaller  $q_{-h}$

# Impact of barrier layer thickness on SST

$$SST_t = SST_{t-1} + \left[ \frac{Q_{obs} + f \Delta q_h + \Delta L}{\rho c_p(h) + \Delta h} \right]_{t-1} \Delta t$$

Observed heat flux

Fraction of  $q_h$  variance explained by BLT

Adjustment to LHF to account for new SST

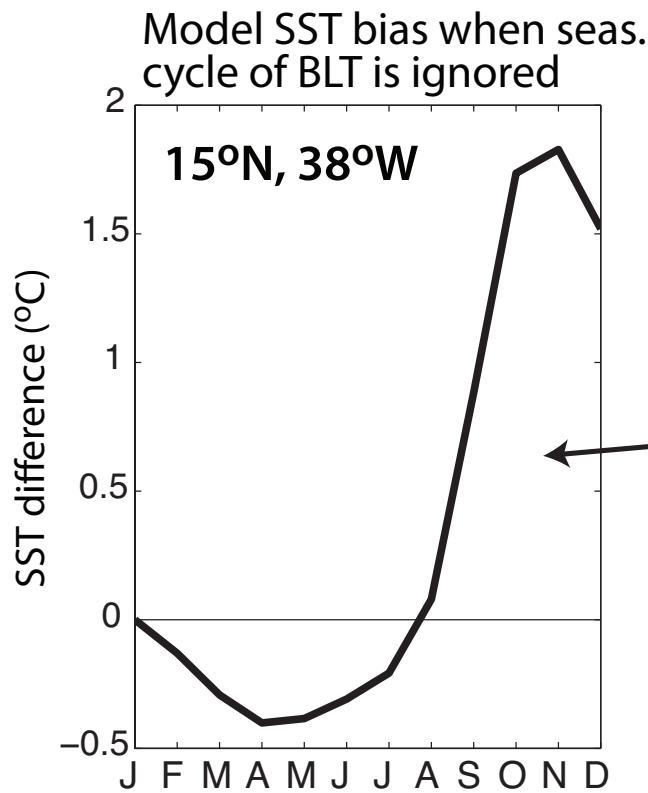
1 month

$\Delta t$

Observed MLD

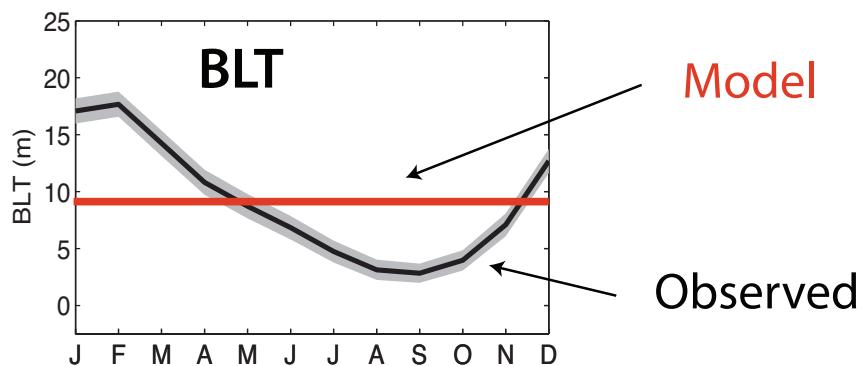
- When BLT is held at its annual minimum value, cold SST biases of 0.5 - 1.5°C develop after one year (25 - 75% of the seasonal amplitude of SST).

# Impact of seasonal cycle of BLT



Model barrier layer is too thick, resulting in too much warming

- More modeling studies needed (e.g., Breugem et al., 2008)



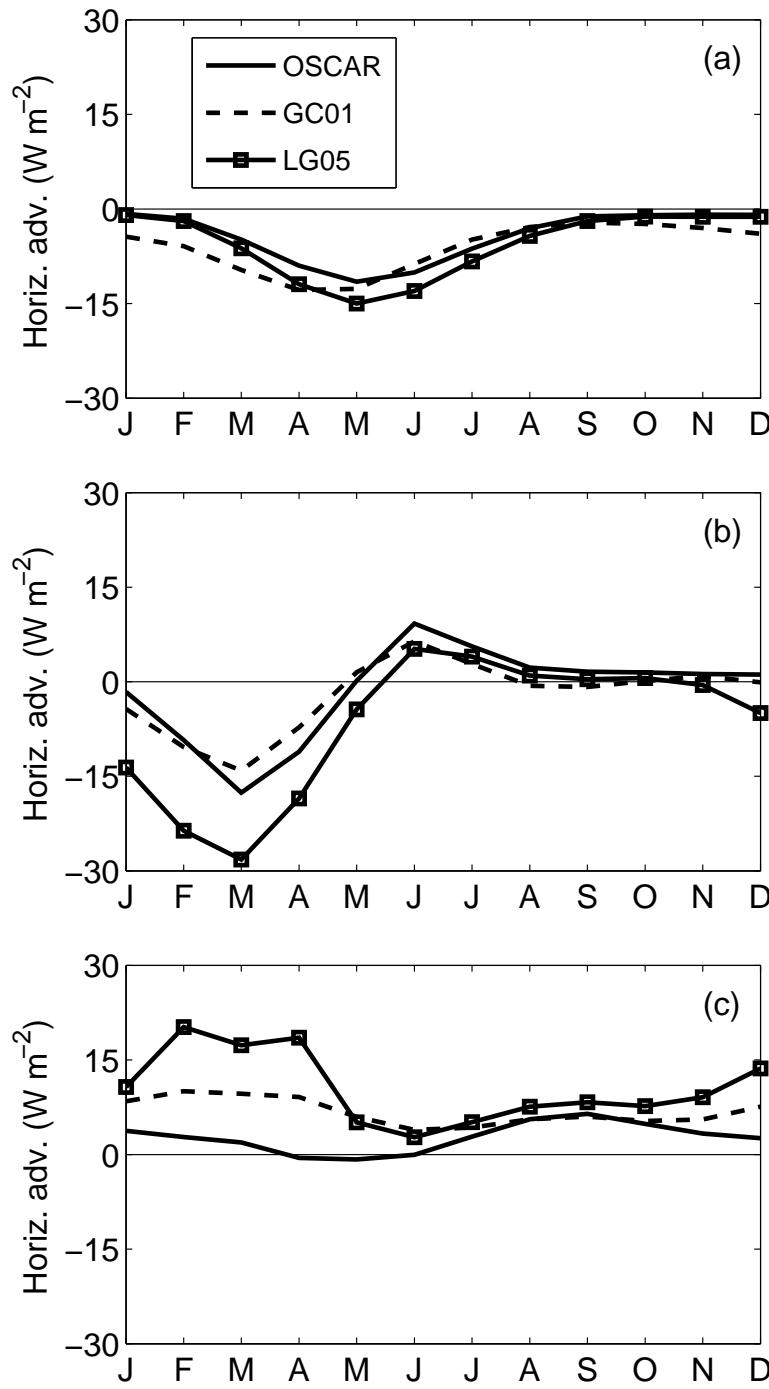
Model

Observed

# Summary

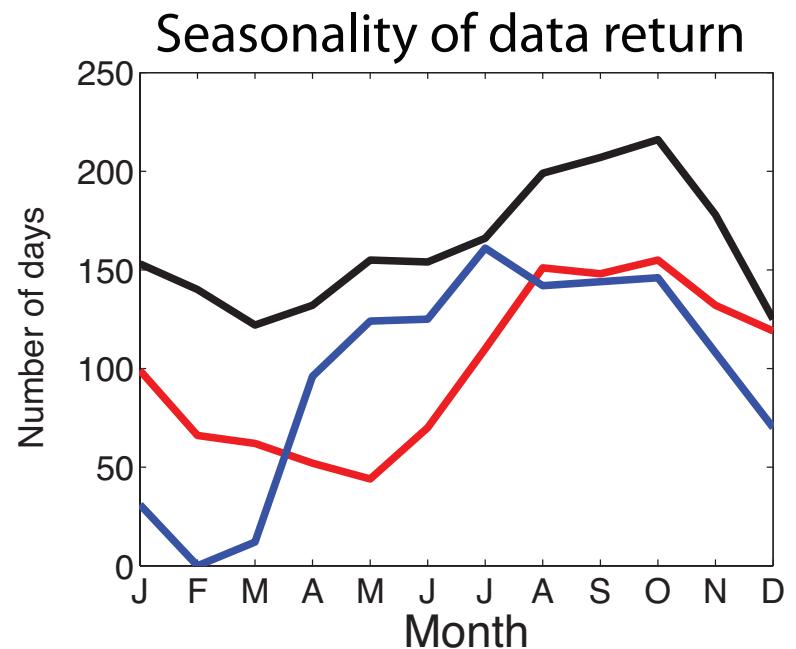
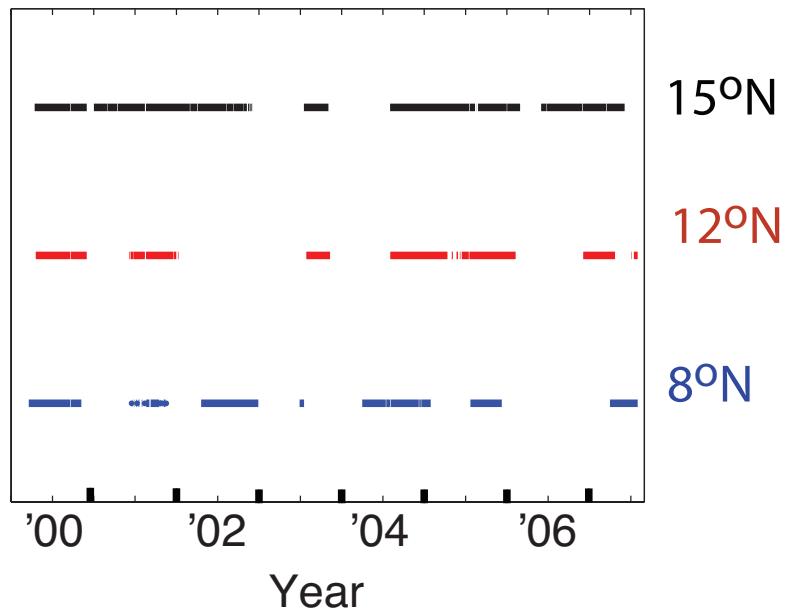
- The seasonal cycle of SST in the central tropical North Atlantic is driven primarily by changes in the net surface heat flux (SWR and LHF).
- There are significant residuals in the heat budgets at each location that we attribute primarily to turbulent mixing at the base of the mixed layer.

- The vertical mixing term is significantly positively correlated with the annual cycle of barrier layer thickness (thick barrier layer is associated with weak turbulent cooling).
- In a simple model, ignoring the barrier layer results in a cold bias of 0.5–1.5°C after one year. Ignoring the seasonal cycle of BLT at 15°N results in a warm bias of ~1.5°C during boreal fall.



# PIRATA data availability

Days with all data available



- Highest data return from the 15°N, 38°W mooring (~ 6 years)

